Microstructure and strength of Ti alloy joints brazed with Ag-28Cu

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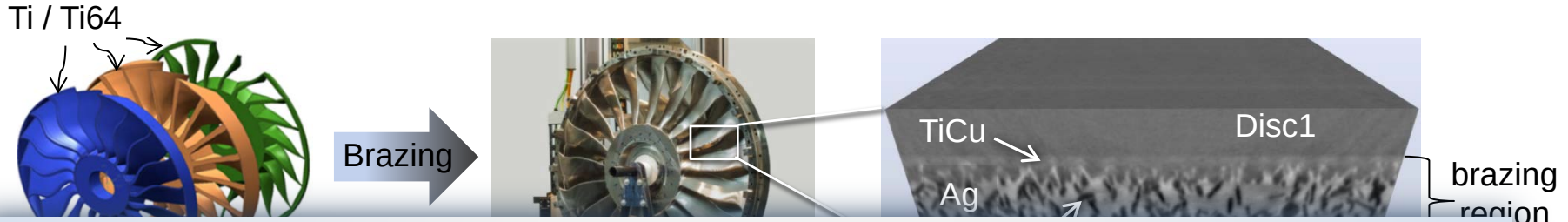
German Aerospace Center (DLR)

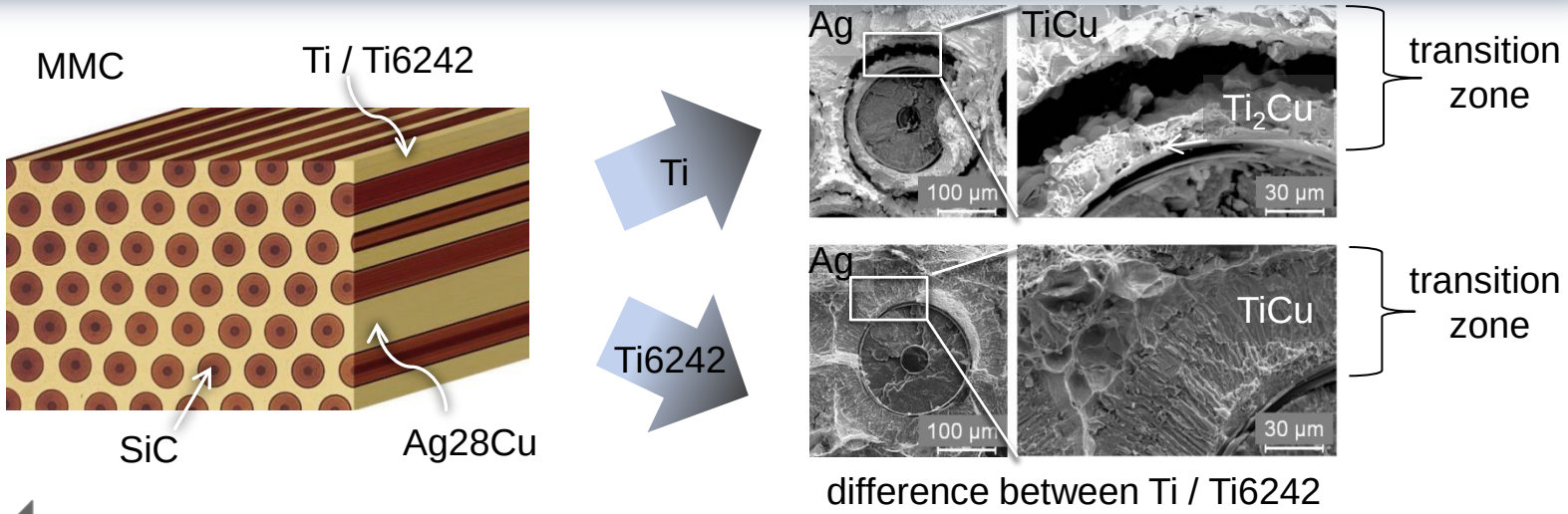
Ti alloys + Ag28Cu systems for aerospace applications

- Brazing: Ti / Ti alloy components joined by Ag28Cu, e.g. aircraft rotor [1]



Research Focus:

effect of alloying elements of Ti alloys:
interfacial reactions ⇒ tensile properties



difference between Ti / Ti6242

[1] F. Kocian et al. CEAS Aeronaut J 6 (2015) 217- 228

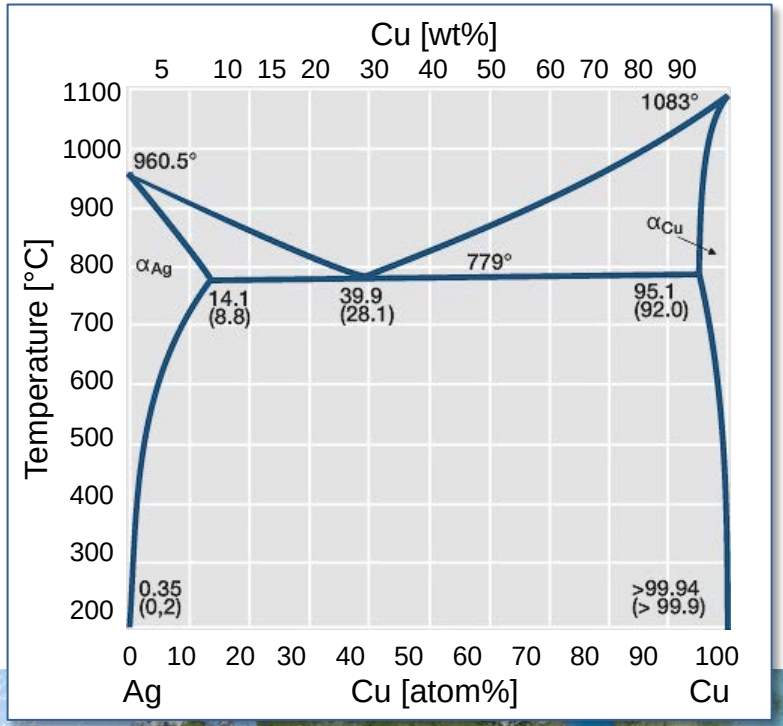
[2] J. Gussone et al. Mater Sci Eng A 612 (2014) 102 – 114

Titanium alloys:

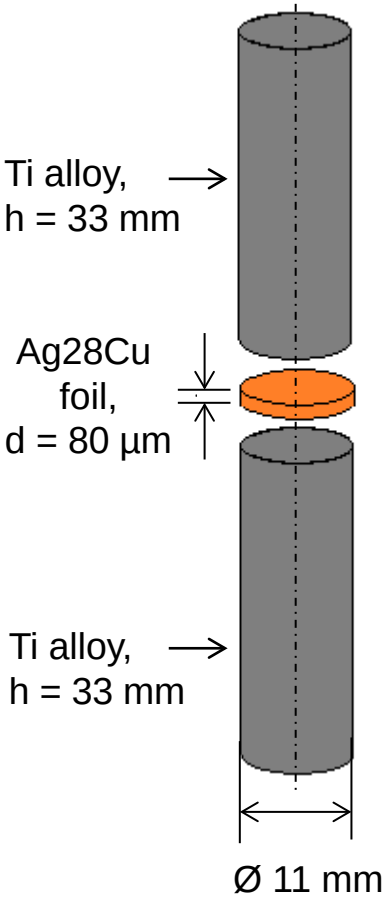
Chemical composition (weight %), max:												
	Ti	Al	V	Sn	Zr	Mo	Si	N	C	H	Fe	O
Ti-CP2	bal	—	—	—	—	—	—	0.03	0.08	0.02	0.30	0.25
Ti-CP4	bal	—	—	—	—	—	—	0.05	0.08	0.02	0.50	0.40
Ti64	bal	6.5	4.5	—	—	—	—	0.05	0.08	0.02	0.50	0.20
Ti6242	bal	6.5	—	2.25	4.5	2.25	0.01	0.05	0.08	0.01	0.25	0.12

Brazing material:

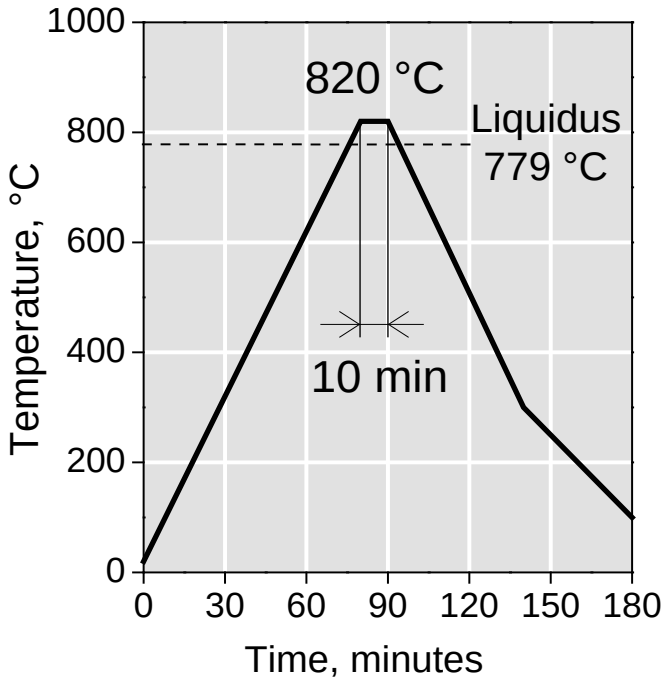
Chemical composition (weight %), max			
	Ag	Cu	Impurities
Ag28Cu	72	28	0.1



Experimental procedure



high vacuum facility

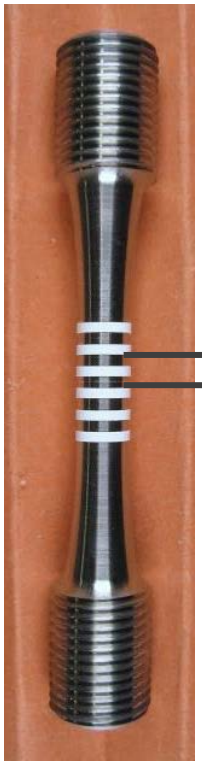


cooling rate < 1 K/s

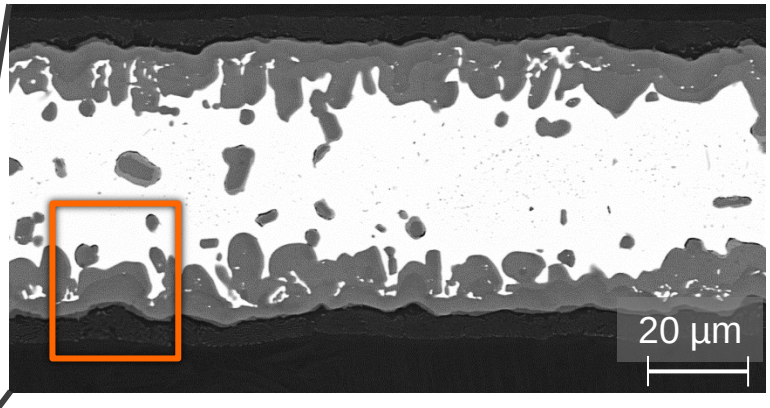
Ø 3.5 mm
dog bone

universal testing machine,
laser extensometer

2D comparative micrographs of the brazing region (SEM)



a) Ti-CP2 / Ag28Cu



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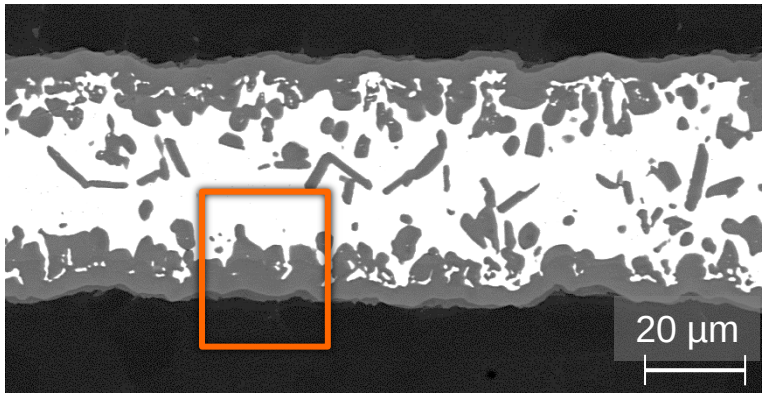
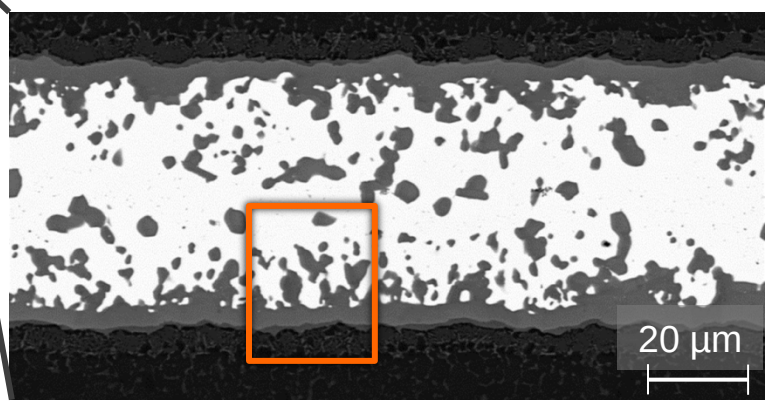
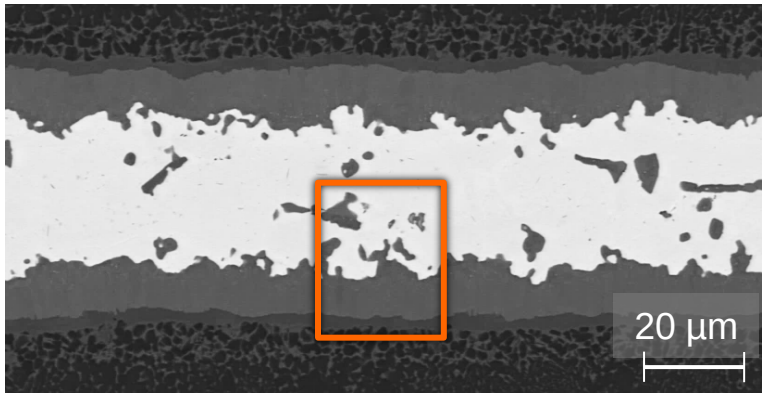


c) Ti64 / Ag28Cu



d) Ti6242 / Ag28Cu



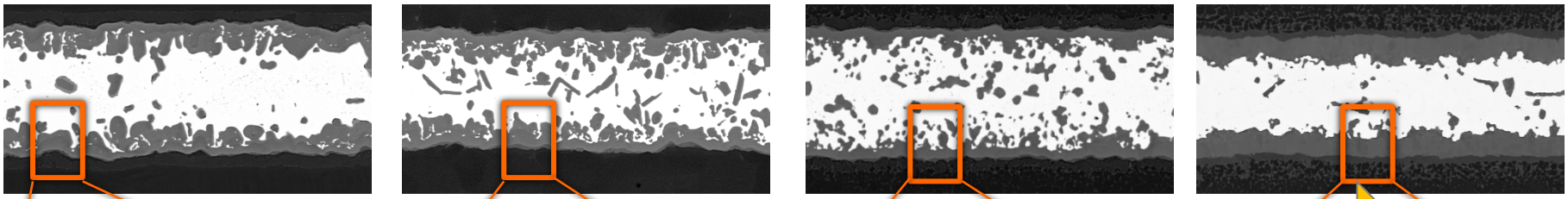
2D micrographs of the brazing region (SEM + EDS + XRD)

a) Ti-CP2 / Ag28Cu

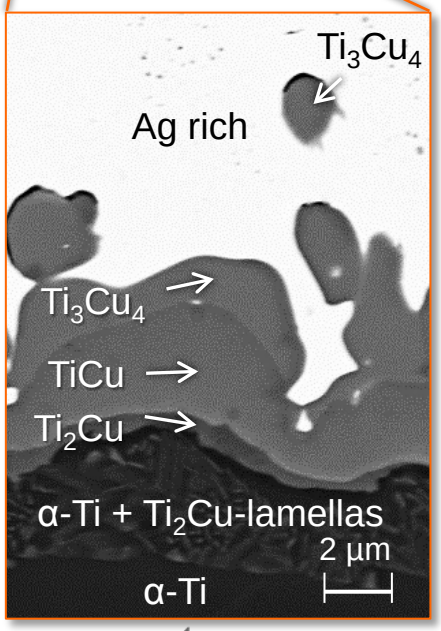
b) Ti-CP4 / Ag28Cu

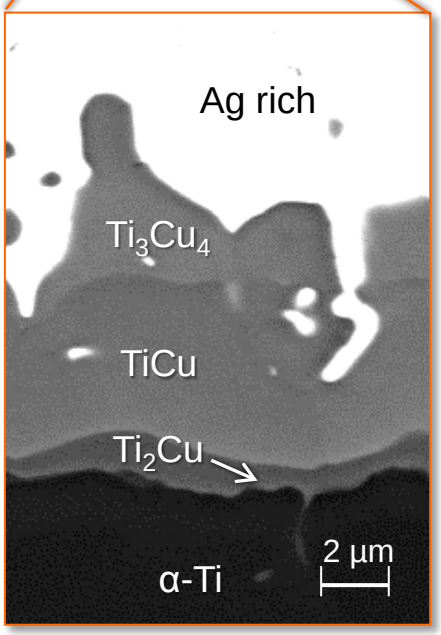
c) Ti64 / Ag28Cu

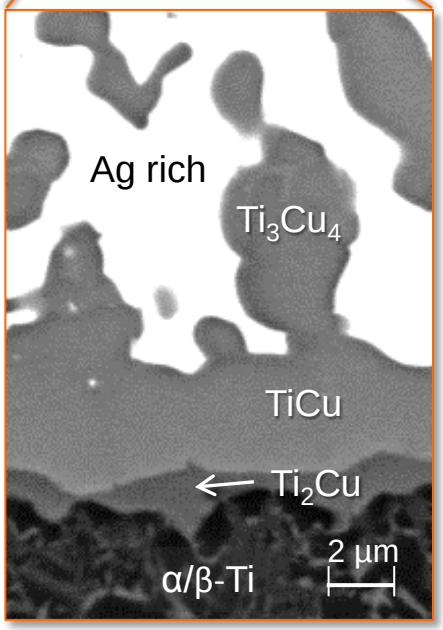
d) Ti6242 / Ag28Cu

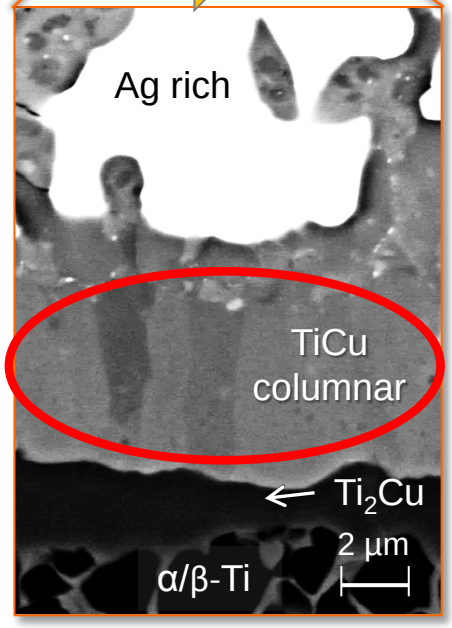


Alloying elements participate in the interface reactions









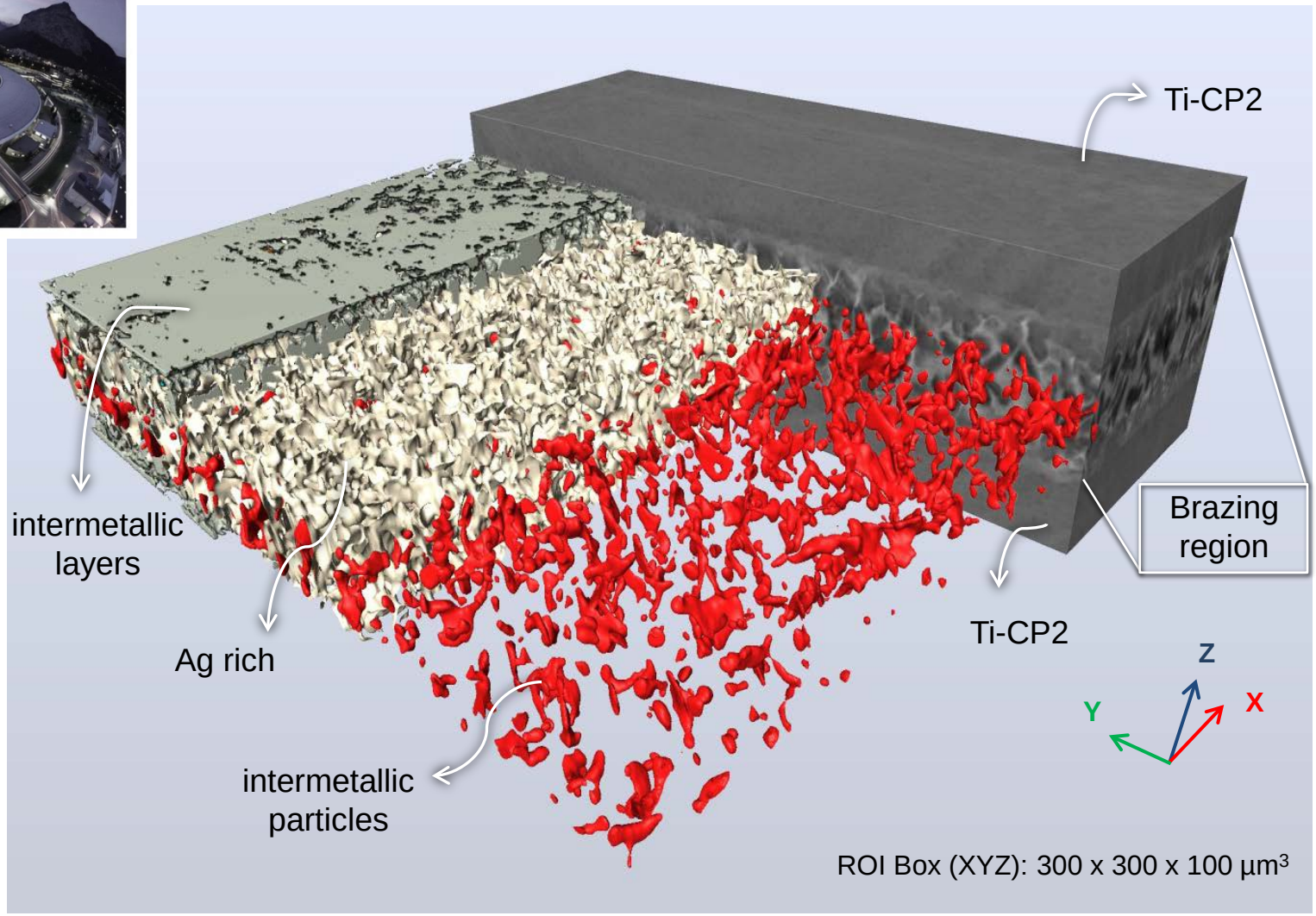
DLR

only phase designation according to phase diagram Ti-Cu

3D investigation of the brazing region by ID-19 (ESRF)

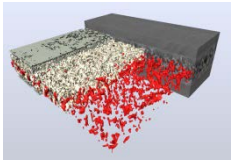
ESRF

Resolution of tomographic scan (voxel size): **0.33 µm³**

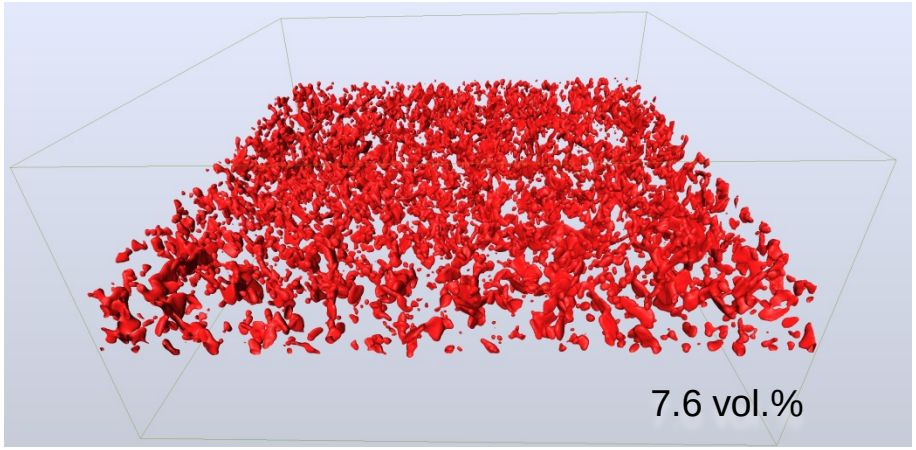


DLR

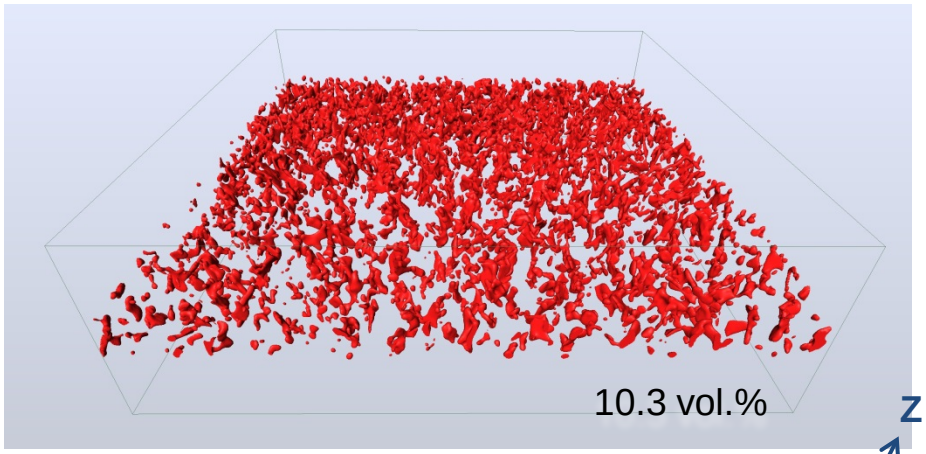
Isometric view of the intermetallic particles



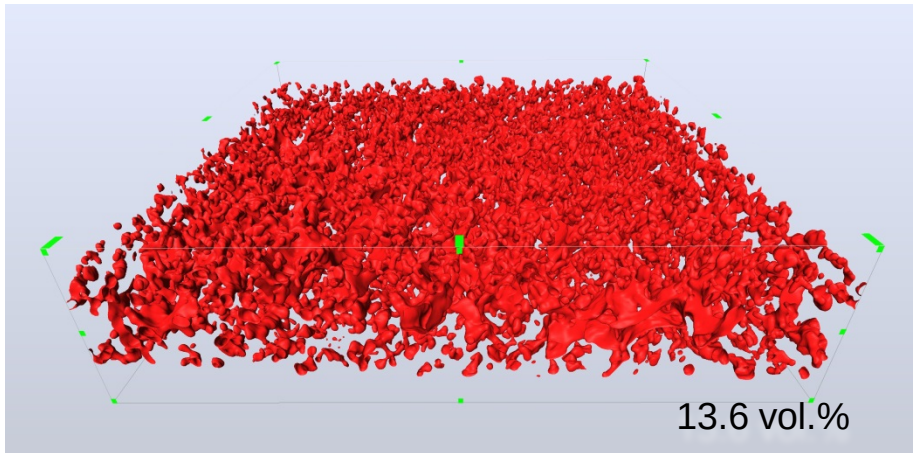
a) Ti-CP2 / Ag28Cu



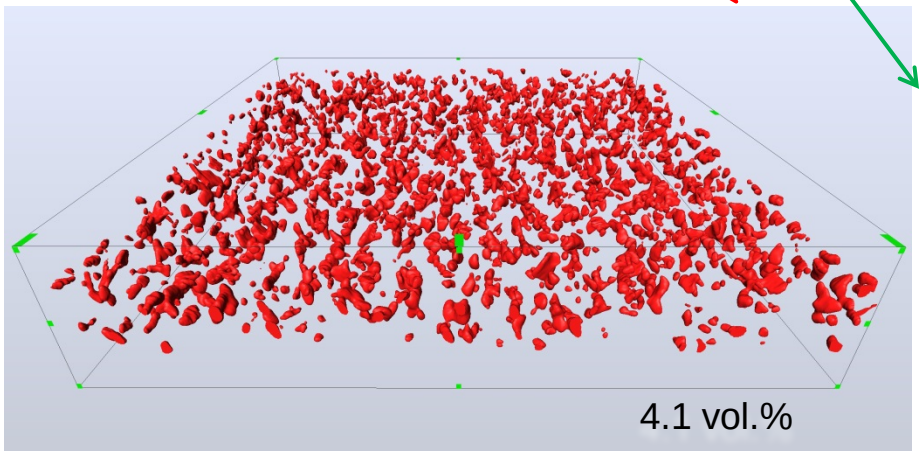
b) Ti-CP4 / Ag28Cu

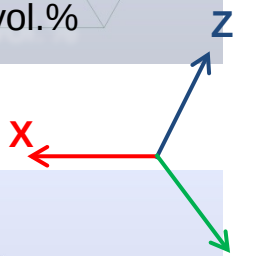


c) Ti64 / Ag28Cu



d) Ti6242 / Ag28Cu



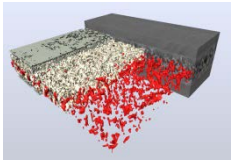


ROI Box (XY): 300 x 300 µm³

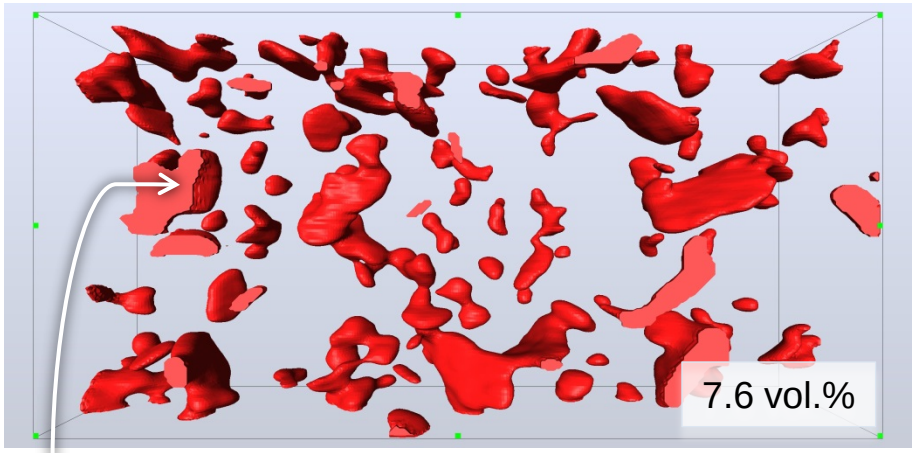
Ag-rich phase is transparent

Measured volume (XZY): 300 x 300 x 50 µm³

Horizontal cuts (top view) of the particles

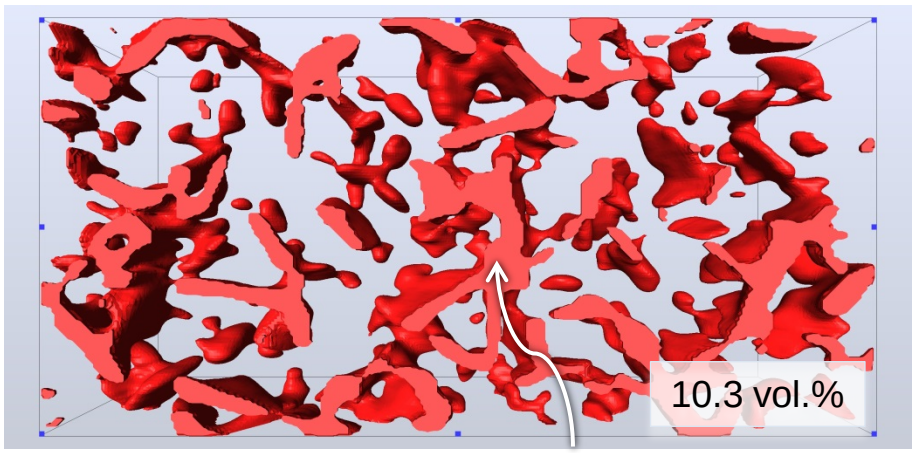


a) Ti-CP2 / Ag28Cu



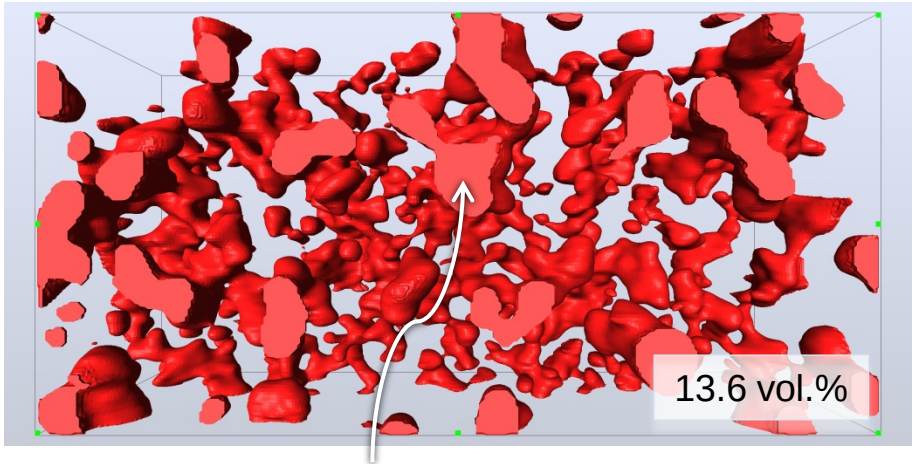
3478 µm³

b) Ti-CP4 / Ag28Cu



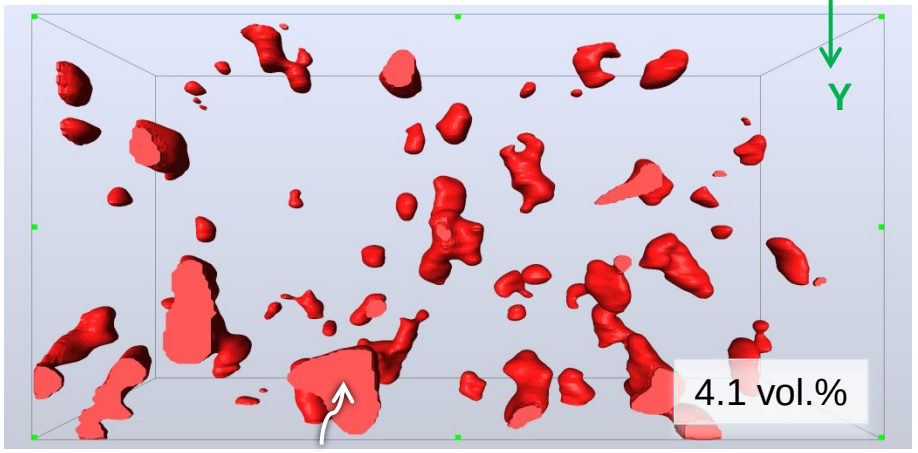
24447 µm³

c) Ti64 / Ag28Cu

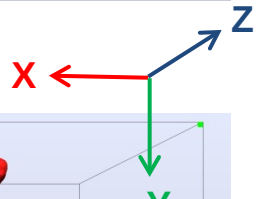


5656 µm³

d) Ti6242 / Ag28Cu



580 µm³

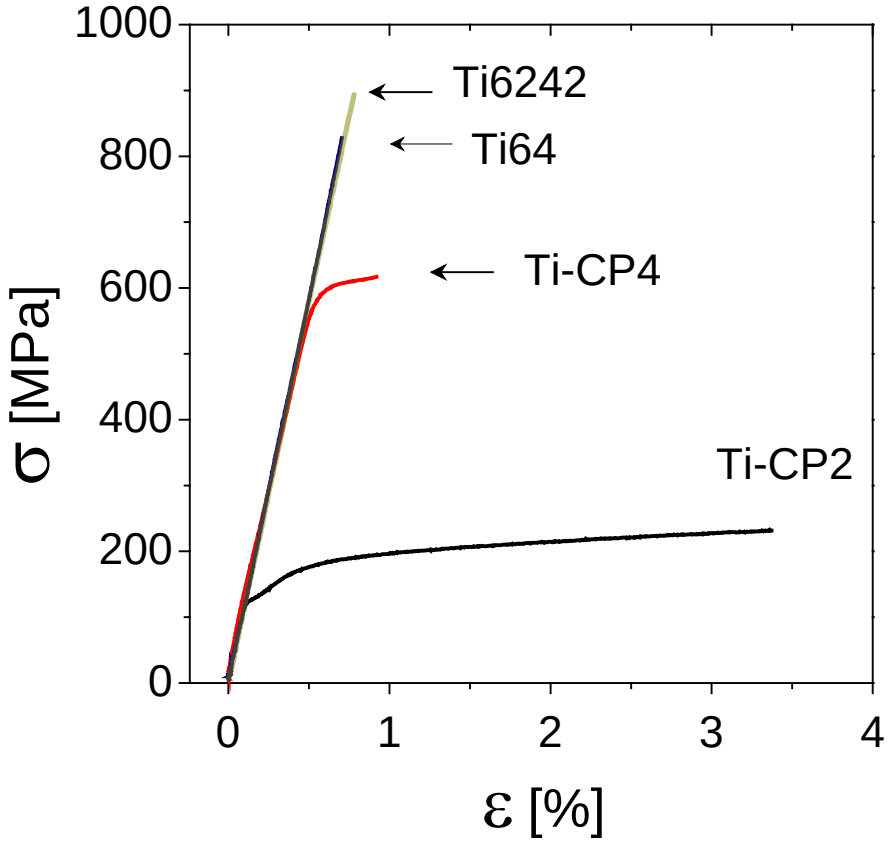


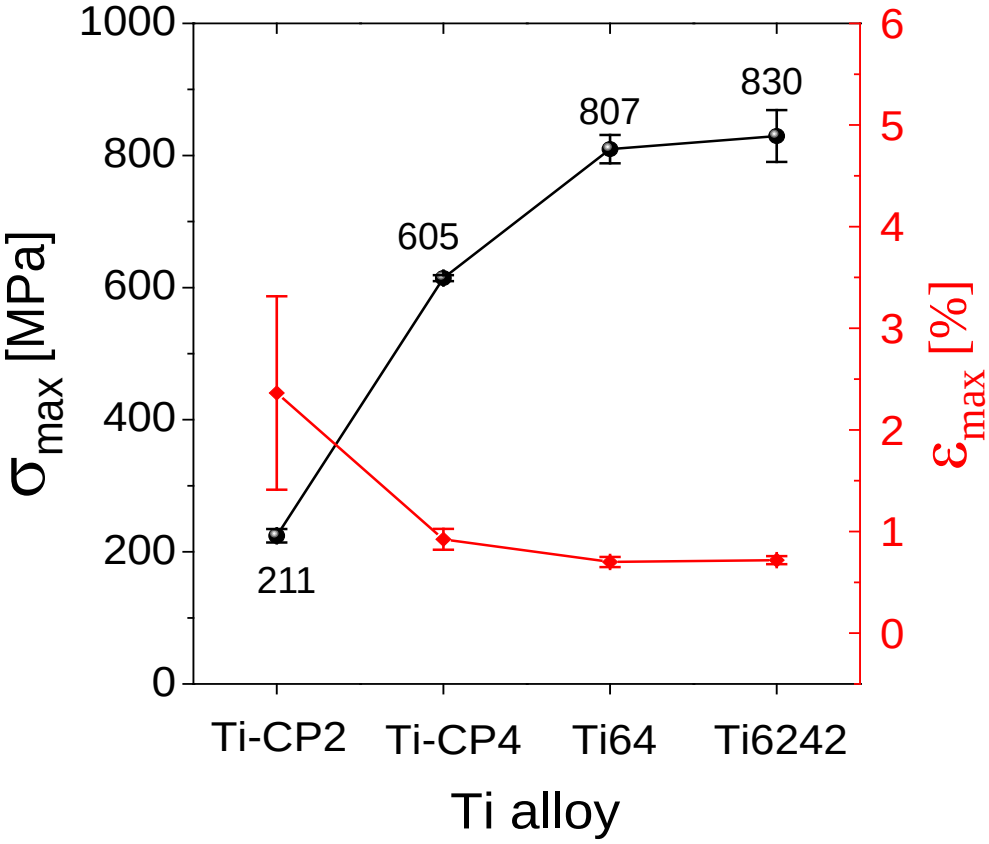
ROI Box (XYZ): 100 x 50 x 25 µm³

Ag-rich phase is transparent

Measured volume (XZY): 300 x 300 x 50 µm³

Stress-strain properties of the brazed samples

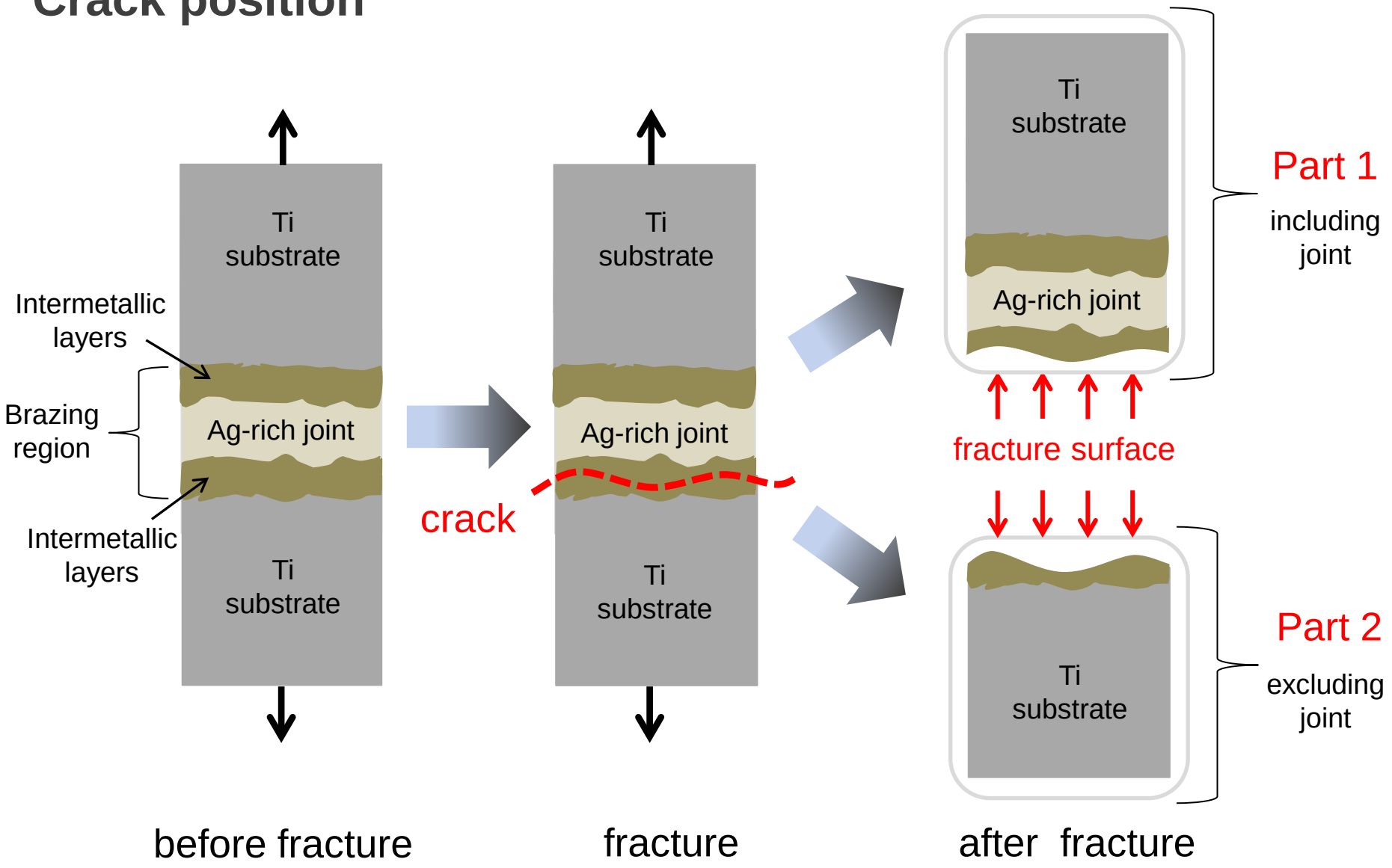




Tensile strength of Ag-28Cu: ~ 300 MPa

average from 3 test samples

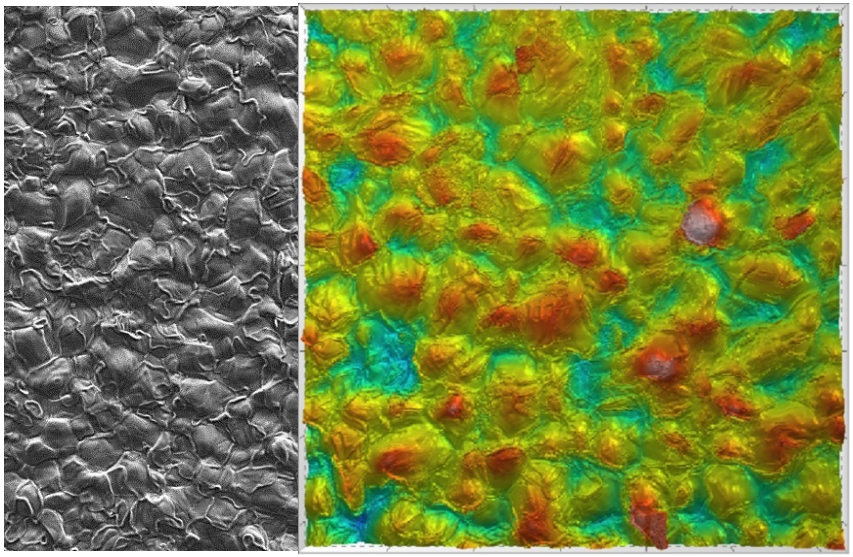
Crack position



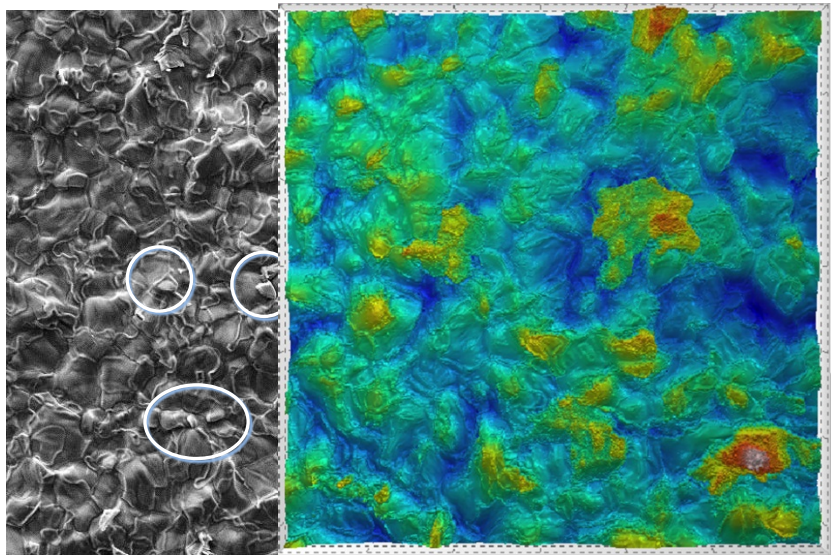
Fracture surfaces (SEM) + Height profile (LSM)

excl. joint

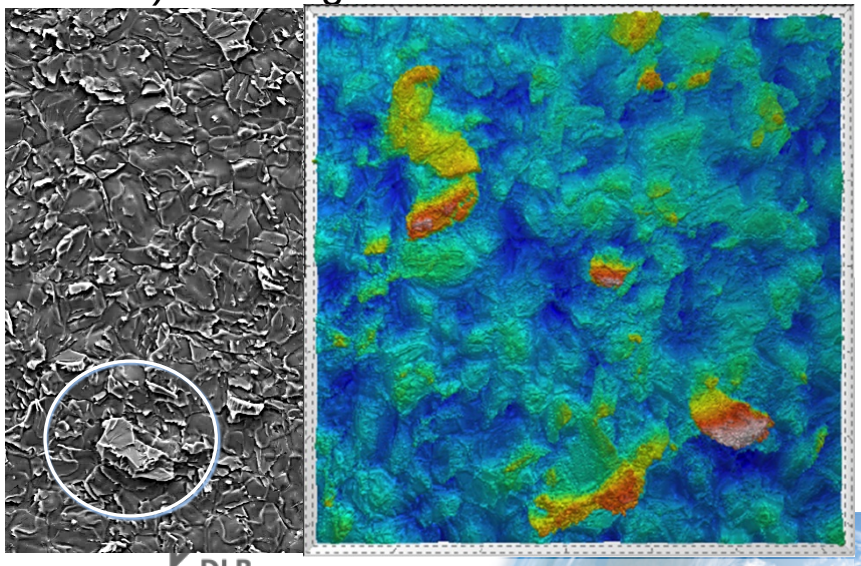
a) Ti-CP2 / Ag28Cu



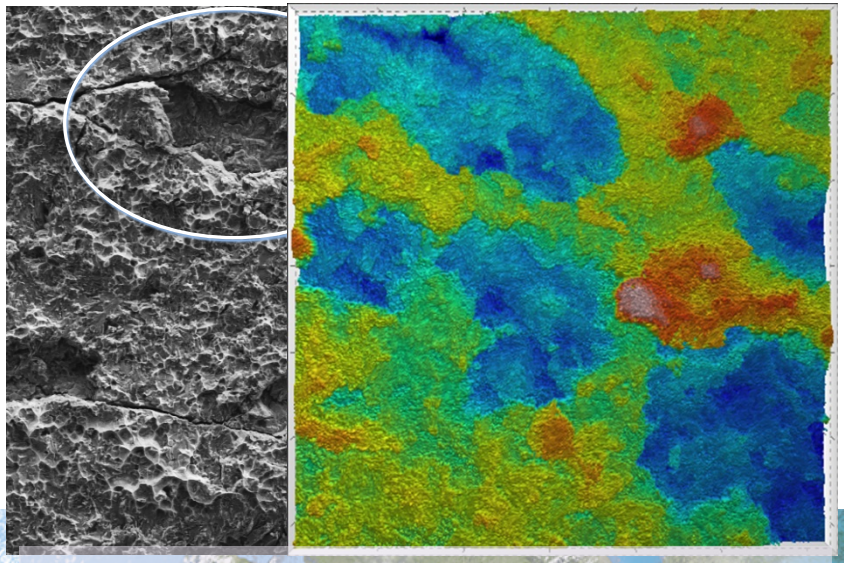
b) Ti-CP4 / Ag28Cu



c) Ti64 / Ag28Cu



d) Ti6242 / Ag28Cu

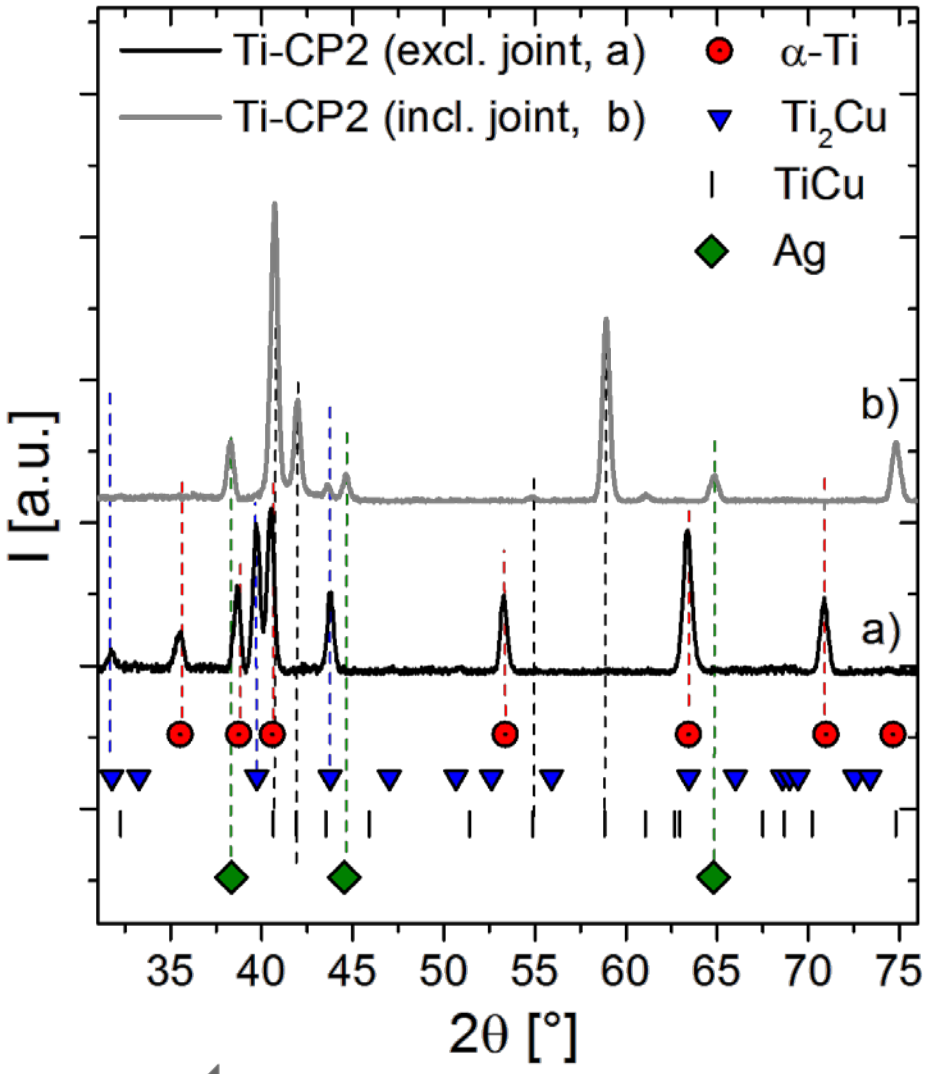


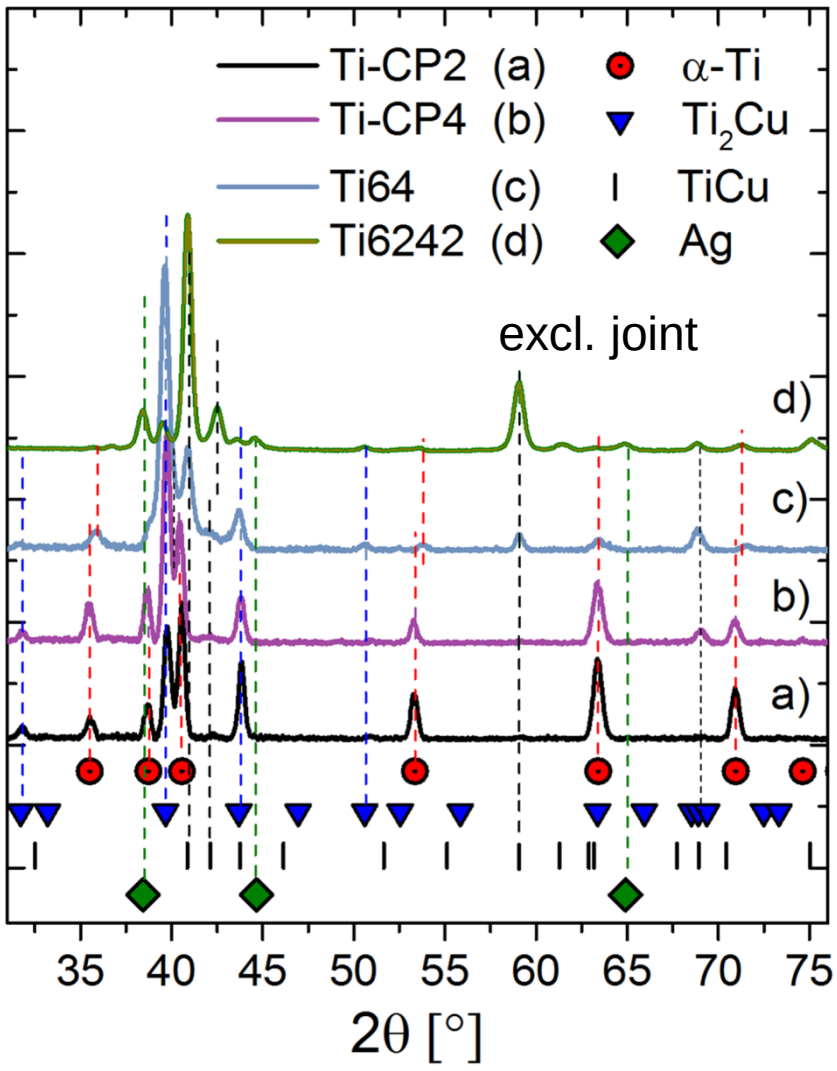
DLR

ISO 25178

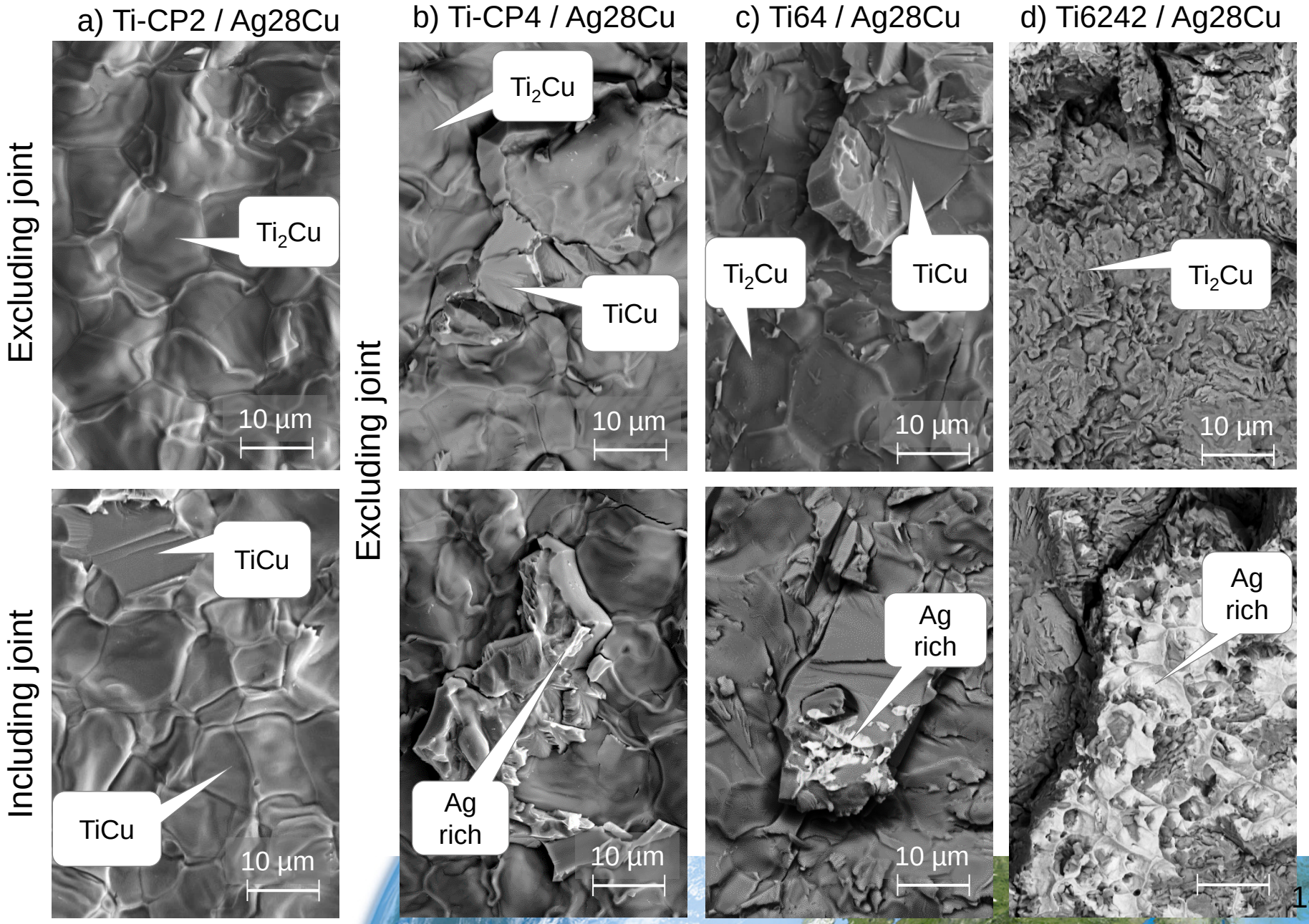
Surfaces measured by LSM (XY): 128 x 128 µm²

XRD of the fracture surfaces



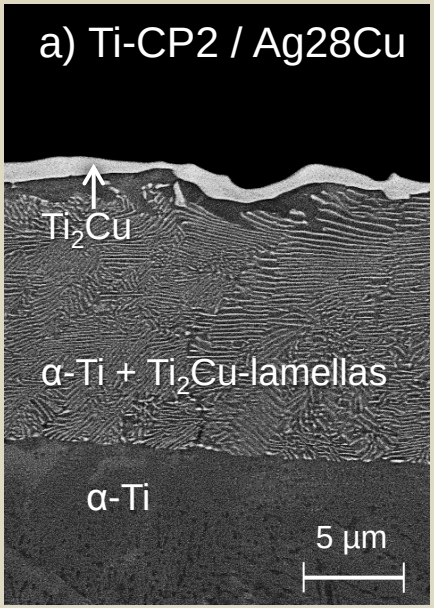


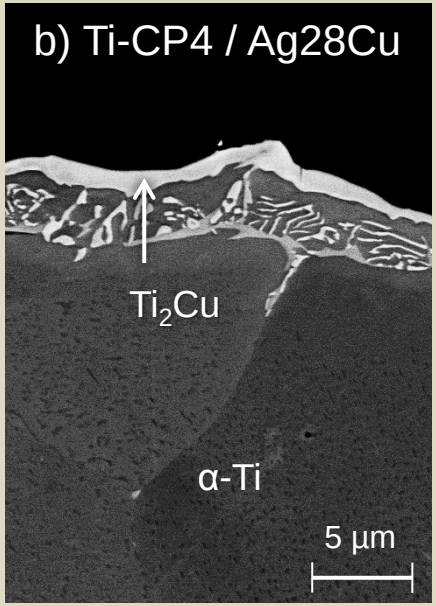
Fracture surfaces (SEM + EDS)

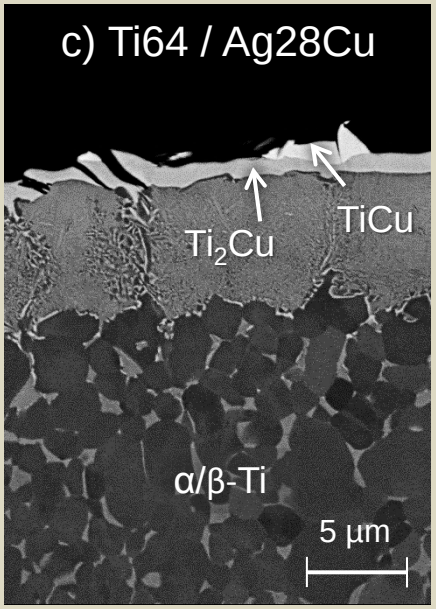


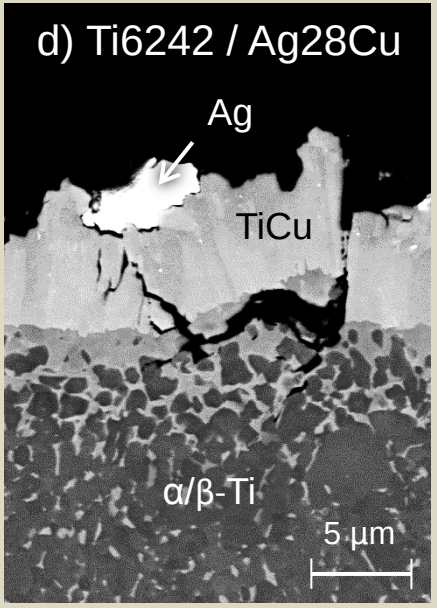
Cross section of fractured tensile specimen (SEM)

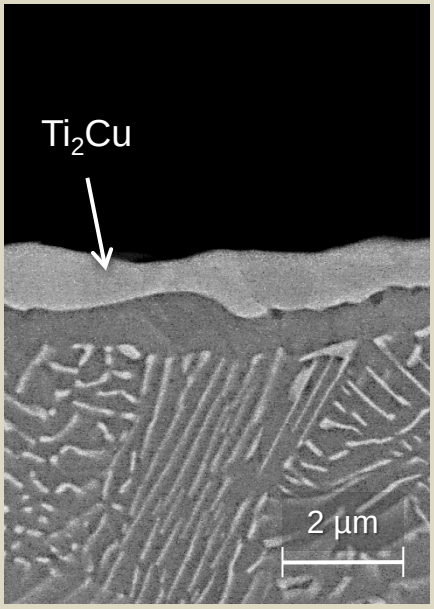
excl. joint

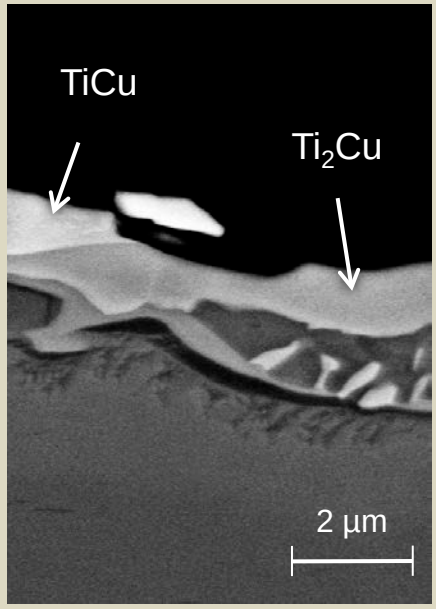


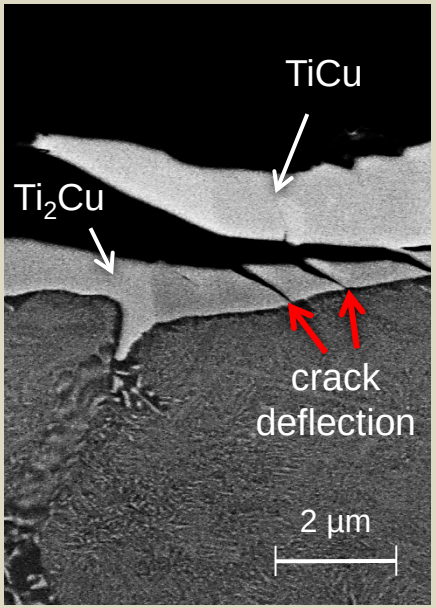


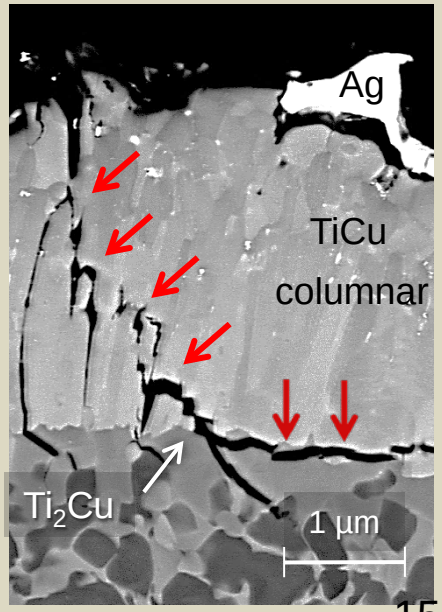




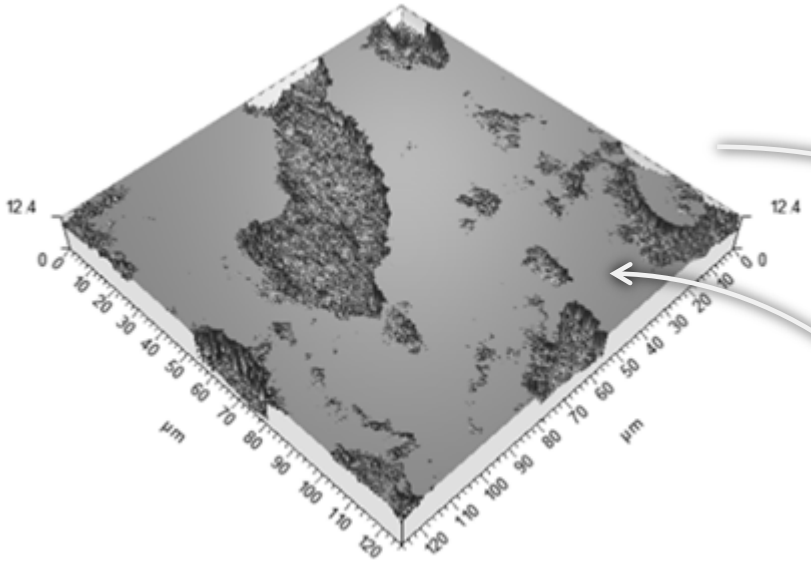


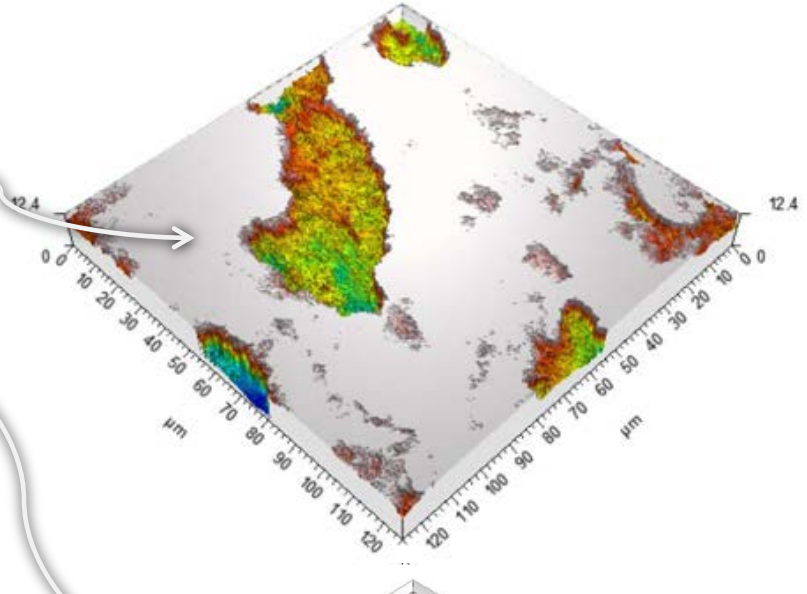




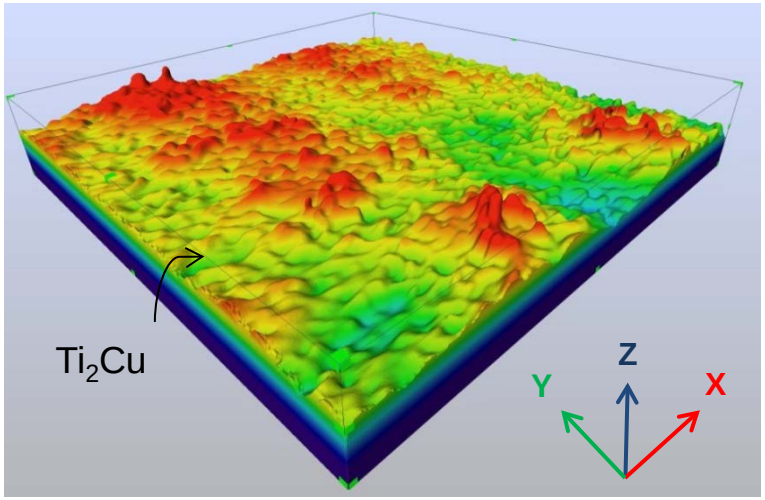


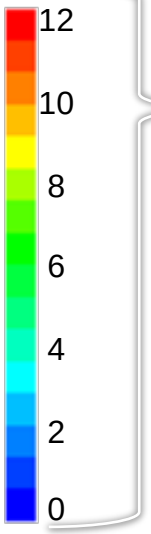
Intermetallic Ti_2Cu layer and fracture surface

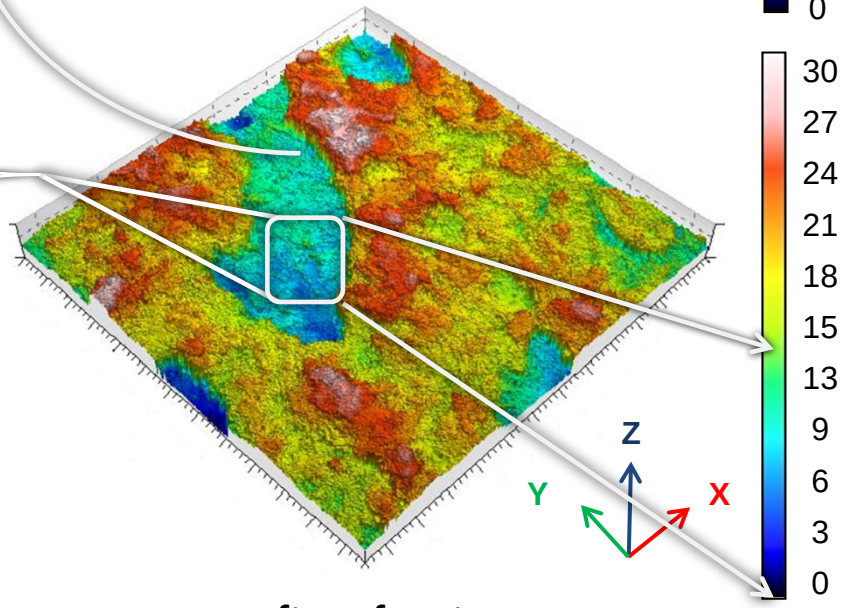




Ti6242 / Ag28Cu







before fracture

obtained by 3D synchrotron tomography

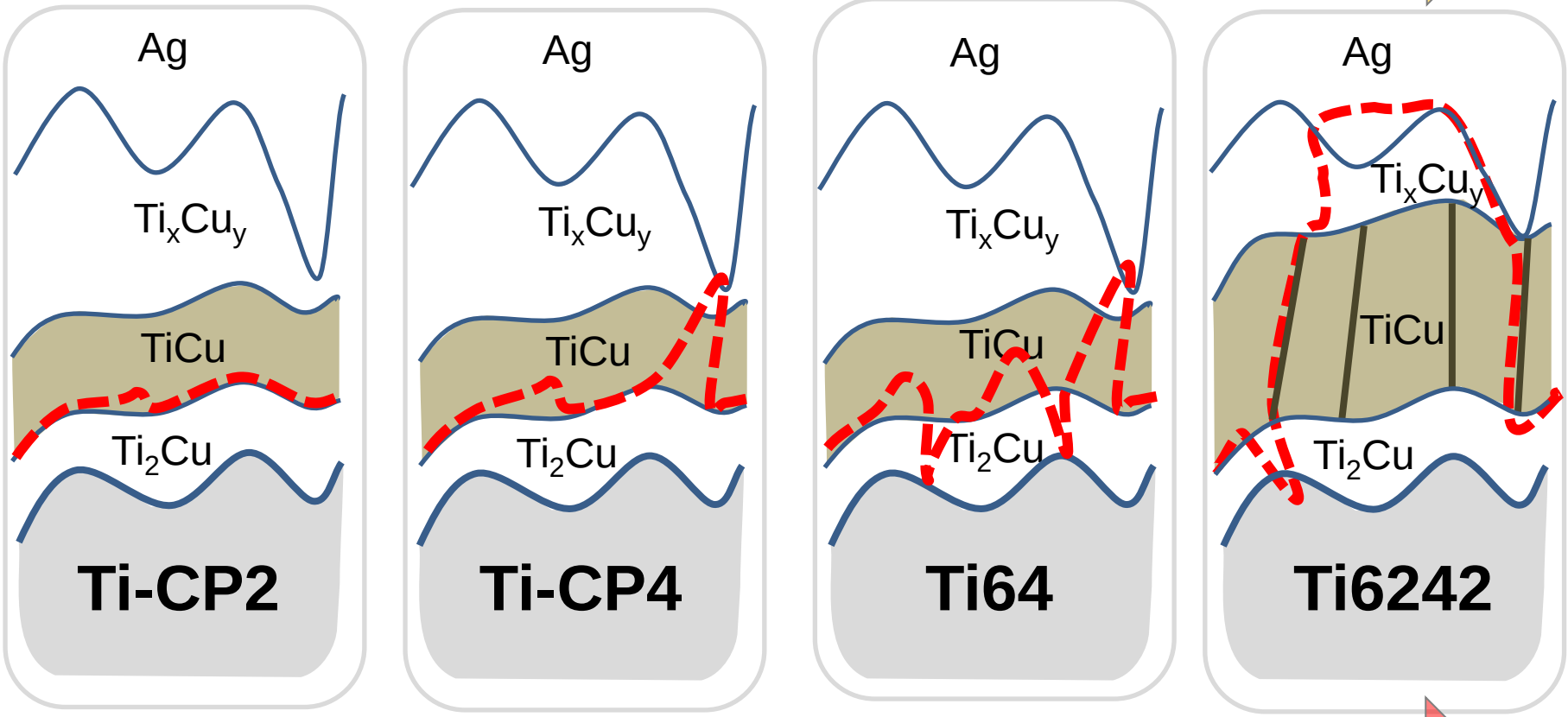
after fracture

measured by confocal laser scanning microscopy (LSM)

Failure modes

a) Ti-CP2 / Ag28Cu b) Ti-CP4 / Ag28Cu c) Ti64 / Ag28Cu d) Ti6242 / Ag28Cu

Alloying elements participate in the interface reactions



Increase of Ti2Cu-TiCu interface strength

Conclusions

- Brazing region: Ag–rich region with Ti_xCu_y intermetallic particles + Ti_xCu_y layers
  - high strength of Ag-rich region due to Ti_xCu_y intermetallic particles
  - crack propagated through the Ti_xCu_y layers.
- Alloying elements of the Ti alloy have a significant effect on the resulting mechanical properties of the brazed material
  - Ti-CP2: strength determined by the interface between Ti_2Cu & TiCu;
  - increasing alloying elements ⇒ increased strength of the Ti_2Cu-TiCu phase boundary and more transcrystalline fracture;
  - Ti6242: Ti_2Cu-TiCu strength is so high that the fracture path deflects through TiCu columns and the ductile Ag-rich phase.

Further investigations

✓	Modification of the brazing region through the additional minor amounts of alloying elements (such as Si, Mo, Sn, Fe etc) in the brazing solder.